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0001,000 -- 0019,000

Today we're going to be talking about Cathodic Protection 101. So, as I mentioned, we do a coatings and corrosions school, and this topic came out of some discussions we had there, that some of the participants really wanted to see, they called it, a "Bill Nye the Science Guy version" of cathodic protection.

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0019,000 -- 0042,000

This is my attempt to give you an introduction. You're definitely not going to become an expert by this talk, but hopefully you'll get some familiarity that makes you recognize where you might be able to use cathodic protection and where we can help you. You can give us a call and we'll put you in the right direction.

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0042,000 -- 0104,000

What is corrosion? Corrosion is the deterioration of a material and or its properties, caused by a reaction with its environment. And we all see corrosion all the time. Typically, what we see is a reaction between a metal and an electrolyte, and in particular, we see rusting of steel in water or soil.

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0104,000 -- 0129,000

Here's a couple examples. Here we have the El Vado Dam spillway. It's steel. It has no coating on it, and this is an example of general corrosion. In the middle here we have a dam stop-wall guide. This was a mild steel bolt with a stainless steel guide, so you have dissimilar metals, or galvanic corrosion occurring here.

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0129,000 -- 0142,000

Then, over here we have bulkhead gates from Seminole Dam, and they've done skip welding on this joint. You can see in between they have crevice corrosion. These are a few different types of corrosion that we see.

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0142,000 -- 0158,000

This can eventually, especially in the case here, it's very apparent that this caused deterioration then, in the concrete, swelling of the concrete. You lose the structural integrity of your pieces, so you want to try to mitigate corrosion where possible.

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0158,000 -- 0219,000

There's several different ways to mitigate corrosion. You can do that by material selections, so for example, choose nonmetallic components. We have some research projects in composite materials here at Reclamation. We also are choosing, sometimes, high-density polyethylene or PVC, things like this, instead of the old materials.

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0219,000 -- 0235,000

The main method of corrosion mitigation is to apply a protective coating to your structures. We're not going to talk too much about that today, but we do have a webinar available on that. For more information we have the coatings team here.

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0235,000 -- 0243,000

Today we're going to talk about cathodic protection, which is what I do day-to-day. And we hope to give you some more information here.

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0243,000 -- 0258,000

So what is cathodic protection? It's a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell. That's kind of wordy, but what we're doing is controlling the corrosion.

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0258,000 -- 0317,000

We're not going to completely stop the corrosion, but we're going to slow it to a rate that is acceptable to us and will give us a longer life of our structure. We're going to do that by defining it as the cathode, and we'll talk more about what that means.

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0317,000 -- 0343,000

Here's some basic slides on how the cathodic protection works. In free corrosion -- you have a diagram here -- you naturally have anodic and cathodic regions on a steel surface. These are just slight differences in the composition, in homogeneities and temperatures, that small regions saw during processing, things like this.

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0343,000 -- 0404,000

This causes them to be anodic and cathodic to each other, which means they have different charges. You'll see that in the diagram we have some that might be at a -0.5 Volts and some that might be a little bit higher than -0.7. This difference in charge drives the corrosion reaction.

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0404,000 -- 0428,000

You need four things for corrosion. You need your anode and your cathode, which we have naturally occurring on steel structures. You need a metallic return path. That would be the steel type itself or the bulk structure itself. Then you need an electrolyte. In our case, this is going to be soil or water that our structure is sitting in.

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0428,000 -- 0445,000

The main method of corrosion mitigation is applying a coating. This is the primary defense against corrosion, and it acts as a barrier between the metal and the electrolyte. We're basically shutting down these two parts.

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0445,000 -- 0503,000

We're placing a barrier between these two components that are required for corrosion. However, a coating may contain defects. At these defects, you can still get corrosion. In this case, we see a pit is forming in our steel.

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0503,000 -- 0528,000

A second method for corrosion protection is cathodic protection. In this case we are controlling the corrosion by making our structure a cathode. We're using an anode, a sacrificial metal, or we'll use a rectifier to drive current and define the cathode as our steel structure. The cathode is the component that doesn't corrode.

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0528,000 -- 0544,000

If you do this on a bare structure, however, it takes an enormous amount of current, and it's often not economical. What we typically do is combine our coating and cathodic protection.

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0544,000 -- 0558,000

We have the coating which provides the barrier and limits the amount of bare steel that's exposed to your soil or your water. Then we use cathodic protection to protect the defects in the coating.

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0558,000 -- 0615,000

I'm quickly going to check my questions, here. This is a pretty important part of site protection, so if any of you have questions about this, this is your basic theory, please let me know and I can answer them.

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0615,000 -- 0629,000

Moving on. As we said, the coating is a primary defense against corrosion, and the cathodic protection works with the coating to protect the structure at the defects in the coating.

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0629,000 -- 0643,000

The most effective corrosion protection system, for both buried and submerged structures involves both a good coating and cathodic protection.

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0643,000 -- 0653,000

There's two forms of cathodic protection that we're going to talk about today, and these are the ones that we use in the Bureau of Reclamation.

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0653,000 -- 0708,000

James, I just saw your comment that you guys got in late. Maybe we can just talk afterwards. If you guys stay on the line, we can go through

those first few questions again instead of reviewing with the whole group. Welcome to the webinar. I'm glad you made it here.

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0708,000 -- 0725,000

The two forms of cathodic protection are galvanic anode cathodic protection and impressed current cathodic protection. With the galvanic and the CP, the structure is directly connected to a sacrificial anode. We'll show you more about what these are.

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0725,000 -- 0744,000

The current to protect your structure is provided by a natural voltage difference between the two metals. For example, if you have a magnesium anode, which wants to corrode more readily than your steel structure, the magnesium will preferentially corrode and protect your steel.

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0744,000 -- 0802,000

Conversely, in impressed current cathodic protection the structure is also connected to anodes, but we use a rectifier to actually drive the current. The rectifier, the external power source, provides that current.

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0802,000 -- 0822,000

I have a few interns working with me this summer. One of them was nice enough to make up a few animations, so here you see a galvanic anode cathodic protection system. You have electrons traveling in your cable, so this is your metallic return path. Then, ions are traveling through electrolyte, in this case the soil.

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0822,000 -- 0836,000

You saw that as this reaction occurs, the anode actually is sacrificed. The anode changes dimensionally and gets consumed in order to protect the cathode.

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0836,000 -- 0901,000

In this case, this is a direct connect system. This you would see sometimes on fittings, for example, metallic fittings on a polymeric pipe. The whole system is below grade. You might also see this if you put galvanic anodes on a gate, for example, where they're directly attached to the gate, like a hull-mount style anode.

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0901,000 -- 0927,000

In this case, there's no place for us to test and see if the system is working. What we usually do at Reclamation is bring your cable above ground and through a test station. In this case, your current is flowing through your test station and we can actually check it here, using a multimeter, and test and see what the current is, and the health is, of your anode.

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0927,000 -- 0941,000

This is why you might see these results in PVC, or they can be galvanized steel as well, on posts above ground. This is the point at which we can test your galvanic anode system.

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0941,000 -- 1005,000

The second type of cathodic protection system is the impressed current. I know they said in this case we provide and drive the current from a rectifier. It's the same principle, though. We have electrons traveling in our cable and in our metallic return path from our anode to our cathode. Then we have ions traveling in the electrolyte, so in the soil or the water.

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1005,000 -- 1029,000

In the case of an impressed-current system, your anode does not typically dimensionally change. You often can't visually see deterioration or aging of your anode, but it can degrade over the life of the anode and become less efficient.

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1029,000 -- 1043,000

Next, we're going to go through some of the system's components just so you can see some examples of what I'm talking about when they refer to anodes, test stations, junction boxes, rectifiers, etc.

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1043,000 -- 1104,000

Here's some examples of your components that are typically underground. Here we have sacrificial anodes, and usually they're magnesium, zinc, or aluminum. In burial they're often magnesium, and in this case, here, when they're buried they're usually in a...This is what the anode itself looks like.

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1104,000 -- 1122,000

Then you purchase it in this cloth bag which is filled with a conductive material, a material that will absorb water and moisture and help kick-start that reaction so that you've got better protection, or quicker protection of your structure.

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1122,000 -- 1151,000

Here's some examples of the metallurgical bonds that I talked about. You always have to have a good bond between your structure and the anode. Here you see an exothermic, a thermal weld, or a CADWELD for example. Then, these are called Handy Caps, or it's a quick repair material. It's got an adhesive on the underside that you can just stick right over your weld material.

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1151,000 -- 1205,000

On the impressed current side, we have different types of anode materials. As I said, these are typically not consumed. You can use a variety of different materials as an impressed current anode. There's some that are more efficient than the others.

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1205,000 -- 1226,000

In this case, these are High-Silicon Cast Iron anodes. They're rod anodes. This is a submerged system and there's a platinum and niobium Wire anode inside this slotted PVC tube. The PVC tube just provides some protection for the wire anode.

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1226,000 -- 1256,000

Here you see some guys installing a deep well anode system, so this would be a set that might be parallel to your pipe at the same depth, this example, over here, for sacrificial anodes. In an impressed current system you can also drill vertically, so if you have a small footprint or small right-of-way you can put an impressed current system in. A Deep Well Anode -- that is what it's called.

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1256,000 -- 1306,000

I have a question-- What happens to the PC, the galvanic cathodic protection, if the test station is damaged or destroyed?

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1306,000 -- 1321,000

That depends how badly it's damaged. Obviously, if you have your...here's an example of a test station. In this case, they have their anodes, there's probably a bond bar on the back of this.

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1321,000 -- 1338,000

They have their anodes conducted to their structure through the test station, which is great for testing, but then if somebody comes and runs this over, and disconnects your tube wires, then you don't have protection of your structure.

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1338,000 -- 1407,000

That's why it's important that we recommend going out and checking everything at least yearly to make sure that your test stations are working and they look good. They haven't gotten pushed over by a cow, or shot at, or run over by a plow truck, or something like this. You want to make sure your test stations are in good order.

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1407,000 -- 1415,000

There's another question that just came up. When is a Platinum Niobium Anode used?

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1415,000 -- 1422,000

They're mostly used in immersion. We use them...What would be some examples, Roger?

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1422,000 -- 1423,000

Pumps, maybe sump...

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1423,000 -- 1424,000

[crosstalk]

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1424,000 -- 1425,000

...pumps.

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1425,000 -- 1436,000

Sump pumps, maybe, application and sometimes also in deep well type application.

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1436,000 -- 1448,000

I'm going back to the above ground components. Here's an example of a rectifier. You may have seen these along the highways, for example, on these kind of telephone poles to support.

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1448,000 -- 1510,000

They're often used in conjunction with a junction box, so your anode cables, you typically have more than one, they come in here, into your junction box. These are shunts and variable resistors, and then you have the cables into your rectifier.

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1510,000 -- 1531,000

Here's some of the hardware that you might see inside your test station or a junction box. General hardware, you have your busbars and your bond bars. These are what you use to connect your anodes to each other and to the structure. We recommend a high-molecular-weight-polyethylene stranded copper cable.

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1531,000 -- 1557,000

This stuff is really big, so one of the main problems that we can see with cathodic protection systems is when people use the wrong cable, and put it in immersion or burial service, the cable itself corrodes. That's another way to damage your system. You will no longer have protection, and that's a lot harder to replace buried, damaged cable than it would be just to replace a test station.

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1557,000 -- 1609,000

We really need to make sure that we're using the right cable for our cathodic protection system. In burial test stations and junction boxes we also recommend using shunts and variable resistors.

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1609,000 -- 1629,000

The shunts are a known-resistance wire, and they typically have these two prongs on them so you can measure voltage across this known resistance and use Ohm's Law of  $V=IR$  to calculate  $I$  which is your current.

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1629,000 -- 1640,000

This is what we would put inside and install inside a test station or a junction box so that we can make sure that your anodes are outputting current and functioning properly.

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1640,000 -- 1701,000

We also can use variable resistors where we can adjust the anodes. If you have 10 anodes on a particular system, you would like them to all be consumed at about the same rate. You can use a variable resistor to adjust the output of individual anodes.

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1701,000 -- 1717,000

Here's what a rectifier might look like. There's many different types of rectifiers, so you could see a lot of different things depending on what brand and style you have. It's a transformer rectifier which we just call a rectifier.

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1717,000 -- 1747,000

There's a transformer rectifier, so you have your coarse and fine tap. You have an AC primary breaker, AC secondary breaker, here, and then you have your positive and negative output. You often also have a voltmeter and an ammeter. These may or may not be accurate, so while it's useful to note the readings on these we also recommend using your multimeter and testing it directly.

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1747,000 -- 1805,000

Again, you can have your shunt, here. It also often has a lightning arrestor, so if this gets struck by lightning that will blow. That's one of the things that you would like to look for when you go and do a rectifier inspection and see if it's be affected by lightning.

63

1805,000 -- 1820,000

Now we've looked at the components. Let's look at some whole systems and what those might look like. This is a galvanic anode cathodic protection system. As I mentioned this is a case for burial, for example on a pipeline. You might have your sacrificial anodes.

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1820,000 -- 1836,000

Here's the magnesium anode itself, and then in the backfill material, in the cloth bag, this would be connected through your test station. Here you see some cables coming into a test station, with a shunt, to your structure.

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1836,000 -- 1903,000

We always recommend that you have some redundancy, and put two cable connections down to your structure in case one of those might get damaged. As well, if you have a pipeline that might have any kind of isolation or joint then we recommend putting electrical continuity bonds across those so that you can protect the whole length of the structure.

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1903,000 -- 1915,000

Here's an example of a galvanic anode system on a gate. These are direct mount anodes. This is what a new anode looks like, and here's an example of that as it gets consumed.

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1915,000 -- 1925,000

Another name for galvanic anode CP is sacrificial anode cathodic protection. A lot of people call it sacrificial anode because you're sacrificing the anode to protect your metal.

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1925,000 -- 1938,000

Again, you're providing a cathodic protection current by galvanic corrosion or sacrificing your anode to prevent corrosion of your structure.

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1938,000 -- 1952,000

This seems obvious, but we want to reiterate that both the structure and the anode must be in contact with your electrolyte. Your structure and your anode need to be in your water or in the soil.

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1952,000 -- 2011,000

For example, on this gate these anodes that are here above the waterline, they're not doing anything. They're not protecting structure, but then also your structure is not in the water where it would corrode more quickly. We want to make sure that we place our anodes below the waterline.

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2011,000 -- 2025,000

Some examples of anode materials for galvanic anode systems as I mentioned already are: in soil and freshwater we typically use magnesium. There's two types of magnesium. There's a high potential magnesium and a standard potential magnesium.

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2025,000 -- 2042,000

You don't need to know too much about that other than if you send us an assistance design form we will specify one or the other on your system based on the design calculations.

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2042,000 -- 2103,000

You may also use zinc in freshwater, but zinc can sometimes passivate and so we need to really look at those conditions before we would specify a zinc anode. Then in brackish water or seawater you would use aluminum and also zinc.

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2103,000 -- 2114,000

Some of the features of the galvanic anode cathodic protection systems -- typically you would use them where you have low current requirements, so a smaller surface area to protect.

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2114,000 -- 2124,000

There's no external power needed which is convenient, for example, sometimes on these gates, and they're also low maintenance.

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2124,000 -- 2134,000

I'm going to go to my questions here -- What is the typical distance between the sacrificial anodes and your structure? That depends on the system that you're designing.

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2134,000 -- 2148,000

You can see here these anodes on the gate are mounted directly on the surface. You see that in ships a lot. We've been doing that on the gates, and so there's almost no distance there.

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2148,000 -- 2203,000

We do need to put some kind of...you can see this curled up material. That's a dielectric shield material, and that's to prevent the anode overprotecting and damaging the coating immediately behind the anode.

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2203,000 -- 2231,000

If we do a system where we have a lot of space, we prefer the anodes to be at a distance -- what we call remote earth. At this distance you can protect a larger area and have a more unifying current distribution if your anodes are at some distance away from your structure. This is something that we calculate when we do our systems design.

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2231,000 -- 2246,000

Next question is: How often do anodes typically last before they need to be replaced? At the Bureau of Reclamation, we design our cathodic protection systems for a 20-year lifetime.

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2246,000 -- 2305,000

In some cases conditions are such that we can't achieve that, but that's what we like to design for. You can expect that unless your environment changes drastically, we like to have them last about 20 years.

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2305,000 -- 2332,000

What happens in encapsulation of zinc? I'm going to guess you're asking about passivation. Passivation is, for example, with stainless steel, the reason why it has a lower corrosion rate is because it forms a passivating layer on the surface. This is a dense oxide layer that doesn't allow oxygen diffusion to your new raw steel.

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2332,000 -- 2351,000

Zinc-- the same thing can happen. In certain conditions you'll get a dense oxide layer on the exterior of your anode and then you'll no longer have a corrosion reaction, or the rate of your corrosion reaction will slow way down and so will no longer be protecting your structure.

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2351,000 -- 2403,000

That's why we need to be careful about the conditions in which we use zinc because if passivation occurs then you will no longer be getting protection.

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2403,000 -- 2418,000

What kind of coating is best for this radial gate? I have one of my coatings colleagues sitting right here, but that's going to depend a lot on your water and the service conditions.

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2418,000 -- 2427,000

That might be something that you'll need to bring a specific example to our attention and our coatings colleagues can help you with that.

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2427,000 -- 2441,000

I'm going to keep going here. Moving on to the impressed current cathodic protection system. In this case we also have anodes, and these are different types of anodes.

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2441,000 -- 2455,000

These are running through a junction box -- which you see two different types of junction boxes here -- and into our rectifier. The rectifier then is connected to our external power source, usually through a circuit breaker.

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2455,000 -- 2505,000

This allows us to turn the whole system off if we need to do repairs. You also have connection to your structure.

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2505,000 -- 2535,000

Then along the line we also have test stations. So in an impressed current system, our anodes are not connected through the test stations since they're connected to our junction box and rectifier. But then we still have test stations so that we can make sure, especially along several miles or hundreds of miles-long pipeline, that all areas of that pipeline are protected. Again, we'll need the electrical continuity bond.

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2535,000 -- 2545,000

You can also have impressed current systems on gates. And so this is an example here at Angostura Dam on a radial gate. They have mixed metal oxides.

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2545,000 -- 2607,000

These actually are mounted on the surface and then they go through the gate and so the wiring comes out the downstream side or the dry side of the gate and then will go to your rectifier which is probably somewhere centrally located over here on a deck or something like that.

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2607,000 -- 2621,000

Here's an example of that mixed metal oxide anode under the waterline. Again, this system provides the cathodic protection current from your external power source. You have to have power available.

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2621,000 -- 2631,000

Direct current power source forces current to discharge from the anode through the electrolytes -- through the water or soil -- and onto the structure to be protected.

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2631,000 -- 2643,000

Again, both your structure and the anode must be in contact with your water or soil in order for the system to be effective.

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2643,000 -- 2658,000

Types of anodes that we use for impressed current, we can use graphite anodes. We can use High Silicon Cast Iron, mixed metal oxides, the platinum or platinum niobium anodes. There's some other examples of things that we can use as well.

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2658,000 -- 2719,000

Impressed current systems are typically...we look at these types of systems when we have, for example, high flow of water or high current

requirements because this gate is about 50 feet across, I believe, so using a very large surface area to protect.

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2719,000 -- 2728,000

These types of systems are better at handling very large or poorly coated structures.

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2728,000 -- 2745,000

We have some questions here. What is the typical distance between the anode and the cathode? Also, how often do you need to place sacrificial anodes? Let me answer the second question first.

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2745,000 -- 2818,000

The distance between your sacrificial anode. If we're going to do a gate then we'll need to look at, for example, the conductivity of your water. How much throw, or how much...the distance that a single anode can protect on a structure is dependent primarily on the conductivity of your soil or your water.

101

2818,000 -- 2833,000

It's going to be something that we do when we run our designs here. On a pipeline...if you're asking about one per mile or one per 10 miles, that makes me think you're talking about a pipeline.

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2833,000 -- 2847,000

On a pipeline that's the same thing. It's going to depend on the conductivity. Or for soils, we typically know the resistivity of your soil, and we often...we'll just have to do those calculations.

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2847,000 -- 2855,000

If it's an impressed current system you may need one anode bed and one rectifier for many miles, 10 miles.

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2855,000 -- 2856,000

<It depends on the number...>

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2856,000 -- 2906,000

Right. It depends on the number of anodes in your anode bed. It's a really hard question and it's something that we would have to look at system-to-system.

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2906,000 -- 2907,000

<Case-by-case basis.>

107

2907,000 -- 2918,000

Right, case-by-case basis is how we do our designs here. How much power per square foot is generally required?

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2918,000 -- 2929,000

We can look at a current density, but I'm not sure if you're asking about power as far as how much power coming from your rectifier. I'm not sure I can answer that question. You have what?

109

2929,000 -- 2936,000

<Probably a lot more interested in how much current we could...[inaudible 29:33]...per square foot. Something like that.>

110

2936,000 -- 2943,000

Again, depending on your environmental factors we try and design for a few milliamps per square foot.

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2943,000 -- 2944,000

<It'd be one to three.>

112

2944,000 -- 2958,000

One to three milliamps per square foot. My colleague, Roger Turcott, is here at my site helping me answer some of these questions. What are typical DC voltages and currents in an impressed current system?

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2958,000 -- 3019,000

Again, that's dependent on a lot of factors: the size of the structure that you're protecting, your soil or water conditions. You can see anywhere from a 5-Volt 1 amp, up to 100-Volts 50 amp rectifiers.

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3019,000 -- 3028,000

It's really dependent on your environmental conditions and these are things that we would need to run through in our calculations in order to figure that out.

115

3028,000 -- 3041,000

<You might tell them that the rectifiers, the ones we use are 120-Volt, but you can get a 220 or 440-Volt rectifier, three phase, single phase. There's a wide variety.>

116

3041,000 -- 3055,000

Right. I'm not sure if you all could hear Roger, but he was just commenting on the fact that we typically use 120-volt rectifiers, but you can also get 240, 440, the whole gamut.

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3055,000 -- 3111,000

I don't know if most of you know, but the oil and gas industry in the United States is regulated and required to cathodically protect their pipelines, so they can have some pretty big systems because they have hundreds and hundreds of miles of pipeline to protect.

118

3111,000 -- 3120,000

They'll just scale their rectifiers according to what their requirements are and the amount of surface area that they need to protect.

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3120,000 -- 3142,000

But these are all questions that we can help you with. If you're sitting through this and you're thinking, Oh, well, I might have this kind of structure, this particular gate, or a tank, or a pipeline, that we could really use cathodic protection on, then give us a call and these are all things that we can help you determine.

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3142,000 -- 3148,000

We do design for all of these structures. That's our day-to-day job.

121

3148,000 -- 3206,000

Where will you find cathodic protection? I just mentioned a few structures. We've seen many of them throughout the presentation. Examples for burial pipelines -- so here's a picture of me. This was a job at Mesa Verde National Park.

122

3206,000 -- 3224,000

We were putting...this was actually a galvanic anode system on a pipeline because they had isolation joints, and we didn't want to dig up the pipeline to put bonding. We were replacing some of their anodes that are magnesium anodes in the backfill bag.

123

3224,000 -- 3245,000

Here's an example. I think this was also a galvanic anode system at Navajo Nation municipal pipeline. You can see again, the bonds and the cable. You can see some of the bonding that they're doing over the joint bonds. When we think of burial, we do a lot of pipelines at Reclamation.

124

3245,000 -- 3302,000

We also do tanks and tank bottoms. If you have a fully buried tank, we protect the exterior of that tank, or if you have a tank, for example, sitting on soil, then we can protect that tank bottom. Also metallic fittings.

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3302,000 -- 3333,000

If we work with some highly corrosive soils, we will often look at the option of putting in a plastic pipe, but right now the fitting options, the joining options, for plastic pipe are not always the best. We often will put metallic fittings on plastic pipes, and in those cases we may connect one or two galvanic anodes exactly to those fittings to protect them from corrosion.

126

3333,000 -- 3353,000

In immersion applications, we have a wide variety of structures that we protect, I've been working more and more on cathodic protection of gates. Here's a couple examples. These are anodes at the gates of the Delta-Mendota Canal. Here's some directly mounted, these are the hull-mount style.

127

3353,000 -- 3416,000

You can see four tabs on these anodes, so they're directly welded to your structure, and this is a magnesium anode, I believe on Angostura Dam radial gate. This is an example from Nimbus Dam, on their radial gate. The hoist-rope joining area, so they had three different types of materials here.

128

3416,000 -- 3434,000

They had stainless steel, mild steel, and galvanized steel, all in this assembly, this hoist-rope assembly. They were having some pretty severe galvanic or similar metal corrosion problems. They came in and had this system designed.

129

3434,000 -- 3507,000

These are all zinc anodes, I believe, and this is what we might call hot spot protection. These anodes are designed specifically to protect this small section of the gate where they were having some big corrosion problems. Tank interiors, we get a lot of distribution tanks or regulating tanks, at Reclamation, and we often protect the interiors of those tanks with air chambers. It's just a different type of tank.

130

3507,000 -- 3530,000

Interiors of pipelines, for example siphons, we might protect the interior. Trash racks, fish screens, pumps. Here's an example of an impressed current system on pump columns and the sump. This is a pretty old picture, and none of us are really quite sure where it comes from, but it's an example there for you.

131

3530,000 -- 3558,000

Question -- Do you have any experience with using impressed currents to repel quagga mussels? In short, no. This isn't something that we've actually been discussing, is how do the quagga mussels affect -- if they affect -- our cathodic protection systems. I'm sorry to say that's not something that we have completely figured out at this point.



132

3558,000 -- 3614,000

So moving into some operation, I just have a few slides left, and I want to say a couple words about operation maintenance and testing. As I mentioned before, the TSC typically designs our cathodic protection systems for a minimum 20-year lifetime.

133

3614,000 -- 3644,000

Sometimes this is not the case, but this is primarily what we do, so you can expect your anodes to last about this long, unless conditions really change. However, you still want to do periodic inspections and repairs of your system. Coating and corrosion visual inspection, preferably you would do these annually, or in some cases when the structure is available through dewatering.

134

3644,000 -- 3707,000

I know some of our structures are not ever available. You put a system in and it goes underwater and stays there. But we'd like to do this annually, and look for corrosion and defects in your coating. You can also look for deterioration of your sacrificial anodes, and those are indicators that you might need to do some repairs.

135

3707,000 -- 3731,000

Check your rectifier every one to two months. You want to check the output of your rectifier, make sure that there hasn't been a lightning strike, make sure that you're still getting current from your rectifier. If you need to adjust your rectifier, we do recommend that you talk to us, or talk to someone who's experienced in cathodic protection.

136

3731,000 -- 3755,000

Because sometimes you might just be having a really wet month, and so your rectifier, your output is off whatever it normally is, but the next month you might be right back to fine. So you don't want to adjust too quickly, because you actually could start to overprotect the system. So every one to two months, check your rectifier.

137

3755,000 -- 3812,000

A pipeline survey at the test station. We recommend that you do this annually. This is when you walk a pipeline and measure what's called an instant OFF potential at each of your test stations to make sure that particular section of pipe is being protected.

138

3812,000 -- 3835,000

This is something that we can also do for you, out of the TSC. For example, my intern who is sitting right next to me, JJ, and my colleague Chrissy, are going to the core pipeline -- the Mni Wiconi core pipeline --

in South Dakota for the next two weeks, and they will be doing one of these pipeline survey tests.

139

3835,000 -- 3850,000

Repair or replace your test stations and other components as needed. Somebody asked the question: What happens if your test station gets knocked over? Well, if your cables are no longer connected, if your structure is no longer connected to your anodes through the test station, then you want to repair that as soon as possible.

140

3850,000 -- 3912,000

That means that you really want to be taking note of those things, especially if you know if your test stations are running across a field with cattle, for example, and you know that those are getting damaged fairly often, then you want to take care and repair and replace them as needed.

141

3912,000 -- 3940,000

Then, replacing the anodes. For the sacrificial anodes, you can visually see the deterioration, for example, if it's on a gate. Obviously, if it's buried, you can't. If you do have a test station, you should be able to test your current output of those anodes. You might also know that you're nearing the end of the design life of your structure, and so you want to make a plan to replace the anodes.

142

3940,000 -- 3959,000

Then the impressed current system, you would also be checking and making sure that the output of your anodes is sufficient. When it drops below our recommended protection levels, then you want to start thinking about replacing those anodes.

143

3959,000 -- 4013,000

I have a question: Your picture of the test point seems to show four wires coming out. When testing the system, what are you measuring, and how do you determine whether it's working properly or not? That goes right into my next slide.

144

4013,000 -- 4036,000

You're testing what's called an instant OFF potential, and we do have an entire webinar on testing cathodic protection systems. This is going to be a one-slide, very quick version of your protection criteria. You may have two wires coming into the test station. You may have three, four, five.

145

4036,000 -- 4100,000

I saw somebody try and shove eight wires into one of those tiny little test stations, and at that point you might want to just buy a junction box. Sometimes it becomes very confusing. We asked contractors to label or

color code, so cables that come into junction boxes or test stations. Sometimes they do, sometimes they don't.

146

4100,000 -- 4125,000

There's a couple things that you want to be testing for. The first is on the slide. You would test an instant OFF structure-to-electrolyte potential. Again, I'm going to refer you for more information to the testing webinar, or send me an email or something. But there's a couple criteria that NACE, which is the National Association of Corrosion Engineers, that they set.

147

4125,000 -- 4145,000

And these are criteria that, in general, if you meet these criteria, you have sufficient protection. One that we talk about a lot is the -850 millivolt criteria. This is, with respect to a copper/copper sulfate electrode, a reference electrode which you'll see right here.

148

4145,000 -- 4214,000

And this is what we use when we test these systems. You would put this in the ground, above your structure, hooked up to the negative lead of your multimeter, so the black lead of your multimeter. Your red lead would go to your structure cable. You would disconnect your structure cable from the anode, and you would like to see that it meets at least a -850 millivolt.

149

4214,000 -- 4238,000

And that means that you have a sufficient cathodic protection on your structure. The other criteria is the 100 millivolt shift. And this means...every metal has what's called a native potential, when you put them in soil or water. For steel, the native potential is typically around -500 millivolts.

150

4238,000 -- 4303,000

The 100 millivolt shift means that if you measure an instant OFF potential of 100 millivolts or more--more negative--then you're going to be protected. For example, on steel, if you know you have a native potential of -500 millivolts, then your instant OFF potential should be at least -600 millivolts.

151

4303,000 -- 4327,000

This will indicate that you have sufficient cathodic protection on your structure. It is possible to overprotect the structure. In addition to these criteria, we also recommend that your instant OFF potential not be more negative than -1,100 millivolts with respect to the copper sulfate reference electrode.

152

4327,000 -- 4357,000

If you go over this, then you might start to damage your coating, or produce some hydrogen and you could have embrittlement of your structure. When we talk about our protection criteria, you'll hear us use the -850 criteria, or the 100 millivolt shift criteria. And this is a very short explanation of what those mean. Please feel free to contact me if you have more questions and want more information on that.

153

4357,000 -- 4424,000

Finally, why do we want to do this? Does it actually work? Here's some evidence that yes, applying cathodic protection can really save you, both in longevity for your structure, and economically can benefit you in the long run. So this graph--Oh, I don't know what that did, sorry about that.

154

4424,000 -- 4446,000

This graph shows a system in Ontario, Canada. It was many miles, hundreds of miles of ductile and cast iron water mains, and this is the number of breaks. This is the number of breaks, and this is when the system did not have cathodic protection on it. You can see, after eight years, it had three breaks.

155

4446,000 -- 4519,000

After 17 years, they are up to 94 breaks. At year 17, they applied cathodic protection to the system. And here's what happens with the number of breaks. It really levels off, and they didn't see many more breaks per year. This is what the trajectory could have looked like. After 25 years, they could have been up to 665 breaks, if they had not chosen to apply cathodic protection.

156

4519,000 -- 4549,000

Here's some information on how it can affect you, economically. Over a 20-year life cycle, cathodic protection is about 58 percent less expensive than continuing with repairs, or you can see what the full replacement cost would be. For this system, it cost them \$5 million for cathodic protection.

157

4549,000 -- 4616,000

But that's less than four percent of the estimated cost to replace the system, which was \$135 million, if they had not installed cathodic protection and continued to have the same trajectory of breaks and had to do a full replacement of your system. Hopefully, that convinces you that cathodic protection can be a really valuable component of a corrosion management program.

158

4616,000 -- 4635,000

Finally, again just to reiterate, the most effective corrosion protection systems for buried and submerged structures involve a good coating and cathodic protection. We do have some manuals, we have many more than these that are shown here, that are available to you.

159

4635,000 -- 4704,000

I encourage you to go look at our website, which is here. I'm told this will be changing next week, Reclamation is having a web update, but if you use this, it will still direct you to the new site. We have all of the webinars. The slides are all published on the website. The videos are not all there, but if you email me, I can send you the videos as well. And then of course all of these references.

160

4704,000 -- 4728,000

Again, here's all of our smiling faces, and we're always willing to help you with your corrosion and coatings and cathodic protection questions, so please feel free to give us a call. I'm going to go back to the questions now, and if you have any more questions at this point, please type those into your question box on the webinar.